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Morphological Comparison of Morningglory (*Ipomoea* and *Jacquemontia* spp.) Populations from the Southeastern United States

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Morningglories are troublesome weeds in row crops and other agricultural areas throughout the United States. Plants of pitted morningglory, sharppod morningglory, and a fertile ''hybrid'' between pitted and sharppod morningglory (hybrid morningglory), were compared with cypressvine, ivyleaf, palmleaf, purple moonflower, red, and smallflower morningglories in greenhouse studies at Stoneville, MS. Plants from each of 76 accessions were studied for number of nodes to first internode elongation; stem color and pubescence; leaf area and dry weight of first four full expanded leaves; leaf blade pubescence on abaxial and adaxial surfaces and margins; leaf color, shape, and lobing; petiole length, color, and pubescence; sepal length, color, and pubescence; and corolla color, diameter, and length. Among these morningglories, the most diverse traits were pubescence and flower characteristics. Greatest morphological diversity was among hybrid morningglory accessions because characteristics were intermediate to pitted morningglory and sharppod morningglory accessions. Sharppod morningglory had five nodes to first internode elongation compared to three nodes in pitted and hybrid morningglory. Corolla color was white (90%) or white with faint pink veins (10%) in pitted morningglory, lavender (100%) in sharppod morningglory, and varied from pinkish lavender (45%), lavender (38%), white (12%), to white with pink veins (5%) in hybrid morningglory accessions. Pitted, red, and smallflower morningglory corolla diameters were not only smaller, but less variable in size than cypressvine, hybrid, ivyleaf, palmleaf, purple moonflower, and sharppod morningglories. Corolla diameter and lengths were most variable in sharppod morningglory accessions when compared to other morningglory accessions. The sepal tip shape was broader (broadly acute to obtuse) in palmleaf and sharppod than in hybrid, pitted, or other morningglories (acute to narrowly acute). In future studies, these morphological traits will be compared to determine if any are correlated with glyphosate sensitivity.

Nomenclature: Cypressvine morningglory, *I. quamoclit* L. IPOQU; hybrid morningglory, *Ipomoea* × *leucantha* Jacq.; ivyleaf morningglory, *I. hederacea* (L.) Jacq. IPOHE; palmleaf morningglory, *I. wrightii* Gray IPOWR; pitted morningglory, *I. lacunosa* L. IPOLA; purple moonflower, *I. turbinata* L. CLYMU; red morningglory, *I. coccinea* L. IPOCC; sharppod morningglory, *I. cordatotriloba* Dennst. IPOTC; smallflower morningglory, *Jacquemontia tamnifolia* (L.) Gresb. IAQTA.

Key words: Accession, biotype, hybridization, leaf morphology, flower morphology.

A total of 342 species in genus *Ipomoea* (Convolvulaceae) are currently recognized in the Americas (Austin and Huáman 1996) and over 500 species of *Ipomoea* and 120 species of *Jacquemontia* are estimated throughout the world (Mabberley 1989; McDonald and Mabry 1992). Based on the compilation by Austin and Huáman (1997) there could be as many as 600 to 700 species of morningglories worldwide. Weedy morningglories in the United States comprise several species, mostly in the genera *Ipomoea* and *Jacquemontia*.

Identification of morningglory species is dependent on an array of traits and characteristics. Various floras utilize presence of vine production, corolla shape, corolla color, leaf shape, leaf lobing, sepal shape, pubescence, and reproductive characteristics to distinguish morningglory species (Correll and Johnson 1970; Fernald 1950; Radford et al. 1968; Yatskievych 2006). The weedy morningglories included the closely related species pitted, sharppod, and *Ipomoea* × *leucantha* (hereafter referred to as hybrid morningglory), each in the Subgenus *Eriospermum*, Section *Eriospermum*, and Series *Batatas* (Austin and Huáman 1997), whereas other morningglory species are not as closely related. Ivyleaf morningglory is in the Subgenus *Ipomoea*, Section *Pharbilis*, and Series *Heterophyllae*; cypressvine and red morningglories are in Subgenus *Quamoclit* and Section *Mina*; palmleaf morningglory and purple moonflower are both in the Subgenus *Quamoclit* and are in Sections *Pendatisecta* and *Calonyctin*, respectively; and smallflower morningglory is in a different genus, *Jacquemontia*.

Morningglories are important and often difficult broadleaf weeds to control in row crops and other agricultural and nonagricultural areas in the southeastern United States. They are highly competitive and reduce both crop yields and harvest efficiency (Crowley and Buchanan 1978; Howe and Oliver 1987). In a survey, McWhorter and Barrentine (1988) found that morningglories were the most troublesome weeds in the United States, regardless of the agricultural system. Despite widespread use of glyphosate following the introduction of glyphosate-resistant crops (Gianessi 2005; Young 2006), morningglories still represent the most common and troublesome weedy genus in southern row crop production (Webster 2000, 2001).

Of the assemblage that contains the weedy morningglories in the southeastern United States, the pitted morningglory complex seems to be one of the most variable in terms of morphological traits and control with glyphosate (Burke et al. 2007; Chachalis et al. 2001; Norsworthy et al. 2001; Norsworthy and Oliver 2002; Reddy et al. 2007; Reddy and Whiting 2000; Shaw and Arnold 2002; Webster et al. 1999). Glyphosate rate and spray coverage were the most important factors that influenced pitted morningglory control, and its tolerance was not attributable to limited foliar absorption or reduced translocation (Koger et al. 2004; Koger and Reddy 2005). Baucom and Mauricio (2004) reported genetic variation in tall morningglory lines, and tolerant lines from an agricultural field in Georgia produced 35% fewer seed in the absence of glyphosate when compared to the most susceptible line. In the ivyleaf–entireleaf

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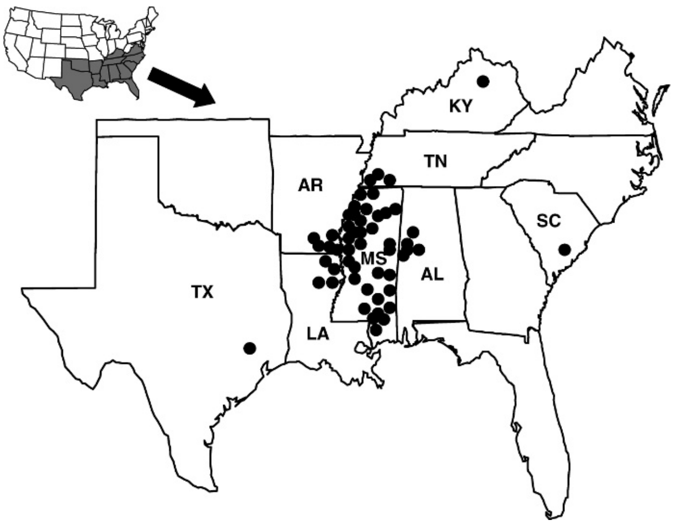

Figure 1. Collection sites for 76 morningglory accessions from eight states (AL, Alabama; AR, Arkansas; KY, Kentucky; LA, Louisiana; MS, Mississippi; SC, South Carolina; TN, Tennessee; and TX, Texas) in the southeastern United States during the fall of 2004 to 2006. More than one accession was collected at several sites. All collections were made between latitude 30°30′N and 38°10′N and between longitude 88°20′W and 96°30′W.

morningglory complex, leaf shape is due to a single gene difference and the ivyleaf shape is the dominant allele (Elmore 1986a). Despite the dominance of the ivyleaf trait, the entireleaf phenotype is more abundant than ivyleaf phenotypes in many fields in the Mississippi Delta Region (Elmore 1986b) and seems to be opposite of expected selection pressures with foliar applied herbicides because an entire leaf provides a larger leaf surface for coverage.

The genetic makeup of pitted and sharppod morningglories in agronomic systems has not been researched and little was known about the diversity of macromorphological characteristics in the pitted morningglory until Stephenson et al. (2006) reported a survey of pitted morningglory. The compatibility and direction of potential gene flow were determined among pitted morningglory, sharppod morningglory, and a purported hybrid of the two by Abel and Austin (1981) and that hybrid, according to USDA, NCRS (2007) is currently known from Arizona, Florida, Louisiana, South Carolina, and Virginia. According to Austin (1997) this morningglory hybrid was initially described from Virginia as a form of pitted morningglory, *Ipomoea lacunosa* L. f. *purpurea* Fernald.

The objectives of this research were to determine (1) macro-morphological parameters to distinguish pitted morningglory biotypes from a fertile ''purported'' hybrid between pitted and sharppod morningglory, and other weedy morningglory species and (2) to determine variability in growth characteristics among morningglory biotypes and species.

Materials and Methods

Seed and herbarium specimens were collected for a total of 76 morningglory accessions from eight states (Alabama [7], Arkansas [5], Kentucky [1], Louisiana [4], Mississippi [54], South Carolina [1], Tennessee [3], and Texas [1]) during the fall of 2004 to 2006 (Figure 1) from cotton gin yards, noncroplands, railroads, roadsides, and corn, cotton, and soybean fields.

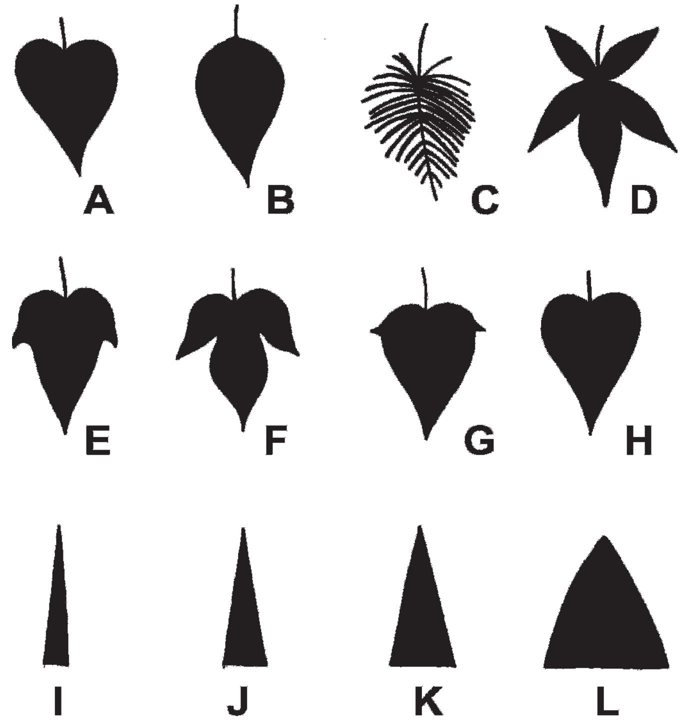

Figure 2. Differential leaf shapes (A, heart-shaped; B, rounded proximally; C, pinnately divided into linear segments = cypressvine morningglory; and D, palmately divided = palmleaf morningglory); leaf lobing (E, shallowly lobed; F, deeply lobed; G, shallowly notched; and H, entire); and sepal shape (I, narrowly acute; J, acute; K, broadly acute; and L, obtuse) observed from accessions of morningglories collected from eight states for comparative morphological studies.

Seeds of each morningglory accession were planted in 70- by 30-cm plastic flats in a 1 : 1 mixture of potting media[1] and soil (Bosket sandy loam, fine-loamy, mixed thermic Molic Hapludalfs). Upon emergence, seedlings were transplanted individually to 15-cm-diam plastic pots filled with a 1 : 1 mixture of potting media and soil. Plants were grown in a greenhouse set to 30/22 C (± 3 C) day/night temperature. Natural light was supplemented with light from sodium vapor lamps to provide at least 14 h of light each day. Plants were watered as needed and were grown in greenhouse until flowering.

Data were collected from individual live and oven-dried plants. The number of nodes to first internode elongation where cotyledonary node = 0 was counted to determine plant growth change from herb to vine. Stem color and presence or absence of pubescence; leaf area and dry weight of first four fully expanded leaves; leaf blade presence or absence of pubescence on abaxial and adaxial surface and margin; leaf shape (Figure 2); leaf lobed and/or notched; leaf color; petiole length, color, and presence or absence of pubescence of first four fully expanded leaves; sepal tip shape, length, predominant color, and presence or absence of pubescence; and corolla color (Figure 3), diameter, and length were recorded. The leaf surface area was measured with a leaf area meter.[2] Petiole length, sepal length, and corolla diameter were measured with a digital caliper[3] (Figure 4). All plants were harvested, pressed, and dried after corolla data were recorded. Plants were clipped at soil level, and herbarium vouchers were pressed in newsprint. Labels for each progeny were prepared citing parental lineage after the procedure described in Carter et al. (2007) to make and preserve herbarium specimens.

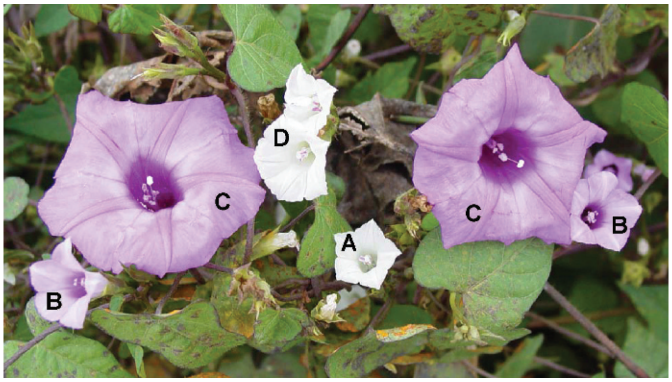

Figure 3. Morningglory flowers showing differences in size and color (A, pitted morningglory; B, hybrid morningglory; C, sharppod morningglory; D, pitted or hybrid morningglory with white flower and pink tinged veins). Corolla color in B is pinkish lavender compared to white corolla with pinkish veins in D.

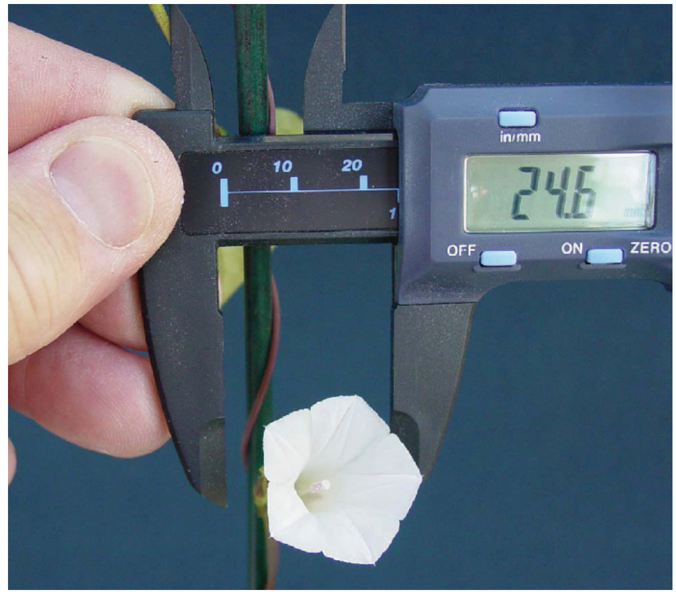

Figure 4. Photo showing digital caliper used to measure morningglory corolla diameter.

There were ten plants for each accession, except where only eight or nine seed germinated for three accessions (two hybrid morninnglory accessions from Covington and Pearl River counties, Mississippi and one pitted morningglory accession from Warren County, Mississippi). All data expressed as percentages were rounded to the nearest 10%. Means and standard errors for quantitative morphological parameters were calculated with SAS.[4] Qualitative data, such as leaf shape and corolla color, were converted to percentages.

Results and Discussion

Node to First Internode Elongation. The average number of nodes to first internode elongation for hybrid, ivyleaf, pitted, and sharppod morningglory accessions was 3.0, 2.9, 2.9, and 4.7, respectively (Table 1). The average number of nodes to first internode elongation was more variable for cypressvine, red, sharppod, and smallflower morningglories than for hybrid, palmleaf, pitted, and purple moonflower morningglories. Among the other morningglory species, the average number of nodes to first internode elongation was greatest in cypressvine, red, and smallflower morningglories (10.9, 7.9, and 6.5, respectively) and least in palmleaf morningglory (2.3) (Table 1). Based on the average node to first internode elongation data, species can be grouped into three distinct categories: (1) three or less nodes—hybrid, ivyleaf, palmleaf, and pitted morningglories; (2) greater than three and less than six nodes—sharppod morningglory; and (3) greater than six nodes—cypressvine, red, and smallflower morningglories. First internode elongation indicates transition of plant growth from herbaceous to viny stage.

Stems. Stems were pubescent in hybrid, ivyleaf, sharppod, and smallflower morningglories (Table 1) although the frequency and coverage of pubescence was greatest in ivyleaf and smallflower morningglories (personal observations). Stems of palmleaf morningglory were entirely glabrous, and less than 40% of the stems were glabrous in accessions of cypressvine, purple moonflower, and red morningglories.

Young main stems were green for all morningglory species and accessions, except for one sharppod morningglory accession (Table 1). As plants matured, the degree of purple on the stems varied among species and accessions, with the exception of smallflower morningglory (data not shown). Based on our preliminary observations, the degree of purple pigmentation in older stems might be related to environmental factors rather than morphological traits useful in segregating species or accessions, and stem color would not be a useful trait to distinguish biotypes within individual morningglory species.

Leaves. Leaf area among morningglories ranged from 5.8 cm^2 in cypressvine morningglory to 155.2 cm^2 in purple moonflower (Table 1). Based on the size of leaf area, three distinct types were identified: (1) small leaf area—cypressvine morningglory; (2) medium leaf area—smallflower, red, sharppod, pitted, hybrid, palmleaf, and ivyleaf morningglories; and (3) large leaf area—purple moonflower. Average leaf dry weight for morningglories ranged from 50 mg in cypressvine morningglory to 570 mg in purple moonflower (Table 1). Based on the leaf dry weights, four distinct groupings were identified: (1) light leaf dry weights—cypressvine morningglory; (2) medium light leaf dry weight—red, smallflower, hybrid, pitted, and palmleaf morningglories; (3) medium heavy leaf dry weight—sharppod and ivyleaf morningglories; and (4) heaviest leaf dry weight—purple moonflower.

Leaf pubescence was highly variable in hybrid, pitted, and sharppod morningglory accessions (Table 2). The pubescence on the abaxial and adaxial leaf surfaces of hybrid, pitted, and sharppod morningglory accessions were usually associated with primary and secondary venation and obvious only under low magnification. Adaxial leaf surfaces were pubescent in 33 to 88% of hybrid and pitted morningglory accessions, respectively. The adaxial leaf surfaces were totally glabrous only in 10% of the accessions, whereas the adaxial leaf surfaces were 70 to 90% pubescent in 11% of the accessions and totally pubescent in 79% of the accessions in pitted morningglory. Average pubescence on leaf margins among morningglory accessions varied from glabrous to up to 50, 90, and 90% pubescent for sharppod, hybrid, and pitted morningglory accessions, respectively.

Table 1. Stem and node traits and leaf area and dry weight for accessions of morningglories (*Ipomoea* and *Jacquemontia*) collected from eight states for comparative morphological studies.

Species	Accession no.	Node to first internode elongation no.	Stem: Pubescent	Stem: Color[a]	Leaf: Area	Leaf: Dry weight
			%		cm^2	mg
Pitted morningglory	37	2.9 ± 0.05	93	100 G	48.5 ± 1.6	130 ± 2
Hybrid morningglory	27	3.0 ± 0.08	98	100 G	48.9 ± 1.9	130 ± 6
Sharppod morningglory	6	4.7 ± 0.30	100	88 G, 12 P	47.1 ± 0.3	190 ± 18
Cypressvine morningglory	1	10.9 ± 0.28	60	100 G	5.8 ± 0.1	50 ± 0.6
Ivyleaf morningglory	1	2.9 ± 0.10	100	100 G	61.9 ± 1.4	200 ± 4
Palmleaf morningglory	1	2.3 ± 0.07	0	100 G	51.0 ± 0.9	150 ± 4
Purple moonflower	1	3.0 ± 0	70	100 G	155.2 ± 4	570 ± 18
Red morningglory	1	7.9 ± 0.18	90	100 G	42.0 ± 1.3	120 ± 6
Smallflower morningglory	1	6.5 ± 0.14	100	100 G	41.6 ± 1.6	120 ± 4

[a] Color: G = Green predominately; P = Purple predominately.

In ivyleaf and smallflower morningglories, both leaf surfaces (abaxial and abaxial) and leaf margin were densely pubescent on the venation and blades and pubescence was obvious without magnification. Palmleaf and red morningglory leaves were totally glabrous. In purple moonflower, the abaxial leaf surfaces were pubescent in 20% of the plants, and all adaxial leaf surfaces and leaf margins were glabrous.

Leaf outline shapes were most consistent among plants in cypressvine (100% deeply pinnately cut into narrow linear segments), palmleaf (100% palmately dissected), purple moonflower (100% entire and heart-shaped), red (100% heart-shaped but notched or shallowly lobed), and smallflower (100% entire and rounded at proximal end of leaves) morningglories (Table 2 and Figure 2A-H). Heart-shaped outline of leaves were observed in 90% of the ivyleaf morningglory plants. Leaf outline shape was variable within and between accessions of hybrid, pitted and sharppod morningglories. Leaf shape of these morningglory species can be grouped into four primary shapes: (1) deeply pinnately cut into narrow linear segments—cypressvine morningglory; (2) heart-shaped—ivyleaf, red, and purple moonflower morningglories; (3) palmately dissected—palmleaf morningglory; and (4) rounded at proximal end—smallflower morningglory. The basic shape of hybird, pitted, and sharppod morningglories were variable within and among accessions and included heart-shaped and rounded shaped leaves.

Because lobing varied in several morningglory species, data were taken for shallow and deeply lobed, shallowly notched, and none (Table 2). No lobes (entire) or shallowly notched leaves were observed in purple moonflower and smallflower morningglory accessions and no additional lobing or notching was observed on individual lobes in palmleaf morningglory. In ivyleaf morningglory, leaves were deeply lobed in 10% of plants, thus showing the accession that we collected was segregating for the ivyleaf and entire leaf forms reported by Elmore (1986a,b). In red morningglory, leaves were shallowly lobed in 20% of the leaves and slightly notched on all leaves. The degree of lobes and notched leaves of hybrid, pitted, and sharppod morningglory were highly variable. In sharppod morningglory accessions, leaves ranged from entire to 50, 90, and 100% shallowly notched, shallowly lobed, and deeply lobed, respectively. Leaves of pitted morningglory accessions ranged from entire to 100% shallowly notched, 10 to 50% shallowly lobed, and 10 to 20% deeply lobed. In hybrid morningglory, leaves were entire in 18% of the accessions, and three accessions developed 10 to 50% shallow notching.

The first four true leaves of cypressvine, ivyleaf, palmleaf, pitted, purple moonflower, red, and smallflower morningglories were all green (Table 2). In hybrid morningglory, the first four leaves were green in 92% of the accessions and in the remaining 8% of the accessions the leaves were green or purple-tinged. The first four true leaves were mostly green for each accession of sharppod morningglory accessions. Leaf

Table 2. Leaf blade and petiole traits for accessions of morningglories (*Ipomoea* and *Jacquemontia*) collected from eight states for comparative morphological studies.

Species	Leaf blade: Accession no.	Leaf blade: Pubescence Adaxial	Leaf blade: Pubescence Abaxial	Leaf blade: Pubescence Margin	Leaf blade: Shape[a]	Leaf blade: Lobes[b]	Leaf blade: Color[c]	Petiole: Length	Petiole: Color[d]	Petiole: Pubescence
		%	%	%	%	%	%	mm	%	%
Pitted morningglory	37	88	62	40	87 H; 13 R	13 SL; 29 DL; 52 SN	100 G	32.6 ± 0.7	2 G; 75 P; 23 T	20
Hybrid morningglory	27	65	38	35	96 H; 4 R	6 SL; 2 DL; 35 SN	99 G; 1 T	32.1 ± 0.8	1 G; 60 P; 39 T	16
Sharppod morningglory	6	33	13	20	95 H, 5 R	32 SL, 48 DL, 12SN	97 G, 3 T	47.2 ± 2.3	40 P, 60 T	72
Cypressvine morningglory	1	0	0	0	100 C	DL	100 G	20.4 ± 0.2	90 P; 10 T	0
Ivyleaf morningglory	1	100	100	100	90 H; 10 R	10 DL	100 G	31.4 ± 0.8	10 G; 10 P; 80 T	100
Palmleaf morningglory	1	0	0	0	100 P	100 DL	100 G	31.0 ± 0.4	100 P	0
Purple moonflower	1	20	0	0	100 H	No	100 G	34.6 ± 0.9	70 P; 30 T	0
Red morningglory	1	0	0	0	100 H	20 SL; 100 SN	100 G	47.7 ± 1.8	90 P; 10 T	0
Smallflower morningglory	1	100	100	100	100 R	0	100 G	18.6 ± 0.6	90 P; 10 T	100

[a] Leaf shapes: H = heart-shaped; R = rounded proximal to petiole; P = palmately divided; C = pinnately divided into linear segments.
[b] Leaf lobe: SL = shallowly lobed; DL = deeply lobed; SN = shallowly notched; No = none.
[c] Leaf blade color: G = green; T = green- and purple-tinged.
[d] Petiole color: G = green; T= green- and purple-tinged; P = deep purple.

Table 3. Flower traits for accessions of morningglories (*Ipomoea* and *Jacquemontia*) collected from eight states for comparative morphological studies.

		Sepal				Corolla			
Species	Accession	Pubescence	Tip shape[a]	Length	Color[b]	Diameter	Length	Color[c]	Dark center
	no.	%		mm	%	——mm——		——%——	
Pitted morningglory	37	91	3 NA; 92 A; 5 BA	10.5 ± 0.2	98 G; 2 P	16.2 ± 0.7	18.4 ± 0.3	88 W; 12 W(p)	0
Hybrid morningglory	27	64	4 NA; 83 A; 13 BA	10.1 ± 0.2	97 G; 3 P	17.1 ± 1.2	19.3 ± 0.4	24 L; 44 PL; 24 W; 8 W(p)	12
Sharppod morningglory	6	82	20 A; 80 BA	11.8 ± 0.8	100 G	37.0 ± 1.5	31.6 ± 1.3	100 L	75
Cypressvine morningglory	1	0	40 A; 60 BA	17.8 ± 0.6	100 G	20.5 ± 0.7	34.2 ± 0.4	100 R	0
Ivyleaf morningglory	1	100	100 NA	9.3 ± 0.2	100 G	36.3 ± 1.3	42.4 ± 0.4	100 B	0
Palmleaf morningglory	1	0	20 BA; 80 O	5.2 ± 0.2	90 G; 10 P	27.0 ± 1.6	21.5 ± 0.3	100 L	40
Purple moonflower	1	0	80 A; 20 BA	22.5 ± 0.3	100 G	49.2 ± 1.1	71.2 ± 1.3	100 L	100
Red morningglory	1	0	100 A	6.6 ± 0.1	100 G	12.2 ± 0.5	27.1 ± 0.5	100 S	0
Smallflower morningglory	1	100	60 NA; 40 A	9.3 ± 0.2	100 G	14.2 ± 0.7	12.9 ± 0.1	100 B	0

[a] Tip shape: NA = narrowly acute; A = acute; BA = broadly acute; O = obtuse.
[b] Sepal Color: G = predominantly green; P = predominantly purplish-tinged.
[c] Corolla Color: B = blue; L = lavender; PL = pinkish lavender; R = red; S = scarlet; W = white; W(p) = white with faint veins.

margins were purple-tinged higher than the first four nodes in hybrid, pitted, and sharppod morningglories (data not shown) and seemed to be an expression of environment rather than phenotypic diagnostic trait to differentiate morningglory biotypes. Some purple-tinged leaves were observed at nodes greater than node 8 in ivyleaf, purple moonflower, palmleaf, and red, and occurrences were more sporadic than in hybrid, pitted, and sharppod morningglory (data not shown).

Average petiole lengths among morningglories ranged from 20.4 mm in cypressvine morningglory to 47.7 mm in red morningglory (Table 2). Based on petiole lengths, three distinct groups were identified: (1) petiole lengths less than 30 mm—cypressvine morningglories and smallflower; (2) petiole lengths 30 to 40 mm—palmleaf, ivyleaf, hybrid, pitted, and purple moonflower morningglories;(3) petiole lengths greater than 40 mm—sharppod, and red morningglories. Within accessions, the average petiole length varied greatest within hybrid, pitted, and sharppod morningglory accessions. The petiole color was variable (green to purple) in each species except in palmleaf where all petioles were purple. Like stem color, this characteristic might be controlled by environmental conditions rather than a morphological trait that will be useful to segregate biotypes within morningglory species. Petioles were all pubescent in ivyleaf and smallflower morningglory and all glabrous in cypressvine, palmleaf, purple moonflower, and red morningglories (Table 2). Over all accessions, petioles were pubescent in 20% of pitted morningglory and within accessions ranged from 10 to 80%. In hybrid morningglory, petioles were glabrous in 30% of the accessions, and in other accessions pubescence ranged from 10 to 40%.

Flowers. Sepal pubescence was variable in hybrid, pitted, and sharppod accessions (Table 3). The degree of pubescence in hybrid morningglory seemed to be intermediate between pitted and sharppod morningglories.

Sepal tip shape was variable in each morningglory species except ivyleaf (100% narrowly acute) and red (100% acute) morningglories (Table 3 and Figure 2 I–L). In sharppod morningglory, sepal tip shape ranged from 20 to 80% acute to broadly acute. Sepal tip shape was 100% acute in most pitted morningglory accessions and varied from acute and narrowly acute in 19% of the accessions. Overall, pitted morningglory plants and accessions' sepal tip shape was 70% acute and none were broadly acute as in sharppod morningglory. Sepal tip shape was more variable in hybrid morningglory when compared to pitted and sharppod morningglories with 6, 10, and 84% narrowly acute, broadly acute, and acute, respectively.

Average sepal length was longest in purple moonflower (22.5 mm) and shortest in palmleaf morningglory (5.2 mm) (Table 3). Average sepal length within species of morningglories did not vary as much as some other traits, e.g., average node to first internode elongation, corolla color, and size. However, average sepal length of these morningglory species can be grouped into three primary groups: (1) less than 7 mm sepal length—palmleaf and red morningglories; (2) 7 to 12 mm sepal length—hybrid, pitted, sharppod, and smallflower morningglories; and (3) greater than 12 mm sepal length—cypressvine and purplemoonflower morningglories.

Sepal color was 100% green for cypressvine, ivyleaf, purple moonflower, red, sharppod, and smallflower morningglories (Table 3). In pitted morningglory, sepal color was 100% green in 84% of the accessions and 80 to 90% green and 10 to 20% predominantly purple in the rest of the accessions. The range of sepal color in hybrid and sharppod morningglories was similar to pitted morningglory.

Average corolla diameters among morningglories ranged from 12.2 mm in red morningglory to 49.2 mm in purple moonflower (Table 3). Average corolla diameters were more variable within hybrid, ivyleaf, palmleaf, purple, and sharppod moonflower morningglory accessions than in cypressvine, pitted, red, and smallflower morningglory accessions. Pitted morningglory corolla diameters were less variable than hybrid and sharppod morningglory accessions. Flower diameter was variable in some accessions identified as pitted morningglory and might be due to ancestry involving hybrid and or sharppod morningglory (data not shown). Austin (1978) suggested that pitted morningglory was a relatively recent branch of the same progenitor line which produced sharppod morningglory, and this close relationship might increase the likelihood of compatibility. We speculate that agriculture and other manmade disturbances have increased the chances for continual hybridization of hybrid, pitted, and sharppod morningglory populations and the mobility of propagules.

Average corolla lengths ranged from 12.9 mm in smallflower morningglory to 71.2 cm in purple moonflower morningglory (Table 3). Corolla lengths were more variable in purple moonflower and sharppod morningglory accessions than in cypressvine, hybrid, ivyleaf, palmleaf, pitted, and smallflower morningglory accessions.

Corolla color was consistently lavender for palmleaf, purple moonflower, and sharppod morningglory accessions; blue for ivyleaf and smallflower morningglory accessions; and scarlet for red morningglory (Table 3 and Figure 3A–D). Corolla color was highly variable among and within hybrid morningglory accessions and might represent populations similar to those reported to breed true from self pollination or crosses between like genotypes (Wallace and Austin 1981). Combined over all hybrid accessions, corolla colors were 24% lavender, 44% pinkish lavender, 24% white, and 8% white with faint pink veins. In pitted morningglory, 88% of the corollas were white and 12% had white with faint pink-veined corollas. A single plant from the hybrid morningglory accession from Yazoo County, Mississippi, produced flowers of two color forms, several flowers with white corollas and one flower with a pinkish-lavender corolla on the same plant. All but five pitted morningglory accessions produced flowers greater than or equal to 80% white corollas. Combined over all pitted morningglory accessions, 90% of the corollas were white and 10% were white with faint pink veins. Wallace and Austin (1981) commented that pitted morningglory might be highly integrated by hybridization; thus the accessions with white corollas and faint pink veins might indicate ancestry that includes hybrid morningglory. Additional research is needed to determine the degree of hybridization in agricultural settings.

None of the morningglory accessions possessed a true petal spot, but corolla color distinctly varied from the distal portion (lighter) to the proximal portion (darker) of the corolla (dark centers) in hybrid, palmleaf, purple moonflower, and sharppod accessions (Table 3). The degree of dark centers was variable in palmleaf, hybrid, and sharppod morningglories. In hybrid morningglory, the centers were not darker than the distal portions of the corollas in 56% of the accessions, whereas the rest ranged from 10 to 50%. Corollas' dark centers were variable in sharppod morningglory. No corolla dark centers were present in cypressvine, ivyleaf, pitted, red, and smallflower morningglory accessions.

Based on our data, corolla color (blue, lavender, white, and intermediates between lavender and white) and size are more reliable characteristics to distinguish these morningglory species than the sepal shape. For instance, ivyleaf and smallflower morningglories possess blue flowers and are distinguished by flower size, e.g., ivyleaf morningglory corolla diameter and length (ca. 36 mm and 42 mm, respectively) are twice the size of smallflower morningglory corolla diameter and length (ca. 14 mm and 13 mm, respectively).

Of the morningglory species evaluated in this study, hybrid morningglory possessed the most variable morphological traits. Pitted morningglory was the second most variable when all traits were compared among hybrid, pitted, and sharppod morningglory accessions. Flower color, size, and sepal shape were also variable for hybrid, pitted, and sharppod morningglories. Corolla dark centers were variable in palmleaf morningglory; however, other characteristics were fairly consistent within this species. According to the distribution provided by USDA, NRCS (2007), our collections of hybrid morningglory increase its known range to include Alabama, Arkansas, Kentucky, Mississippi, and Tennessee, and based on this knowledge, it should be expected in North Carolina and Texas and possibly as far north as southeastern Missouri. These results indicate that leaf shape and size, corolla color and size, and node to first internode elongation are the most useful traits to distinguish among cypressvine, hybrid, ivyleaf, palmleaf, pitted, purple moonflower, red, sharppod, and smallflower morningglories. Other traits, leaf pubescence, leaf lobing, and sepal shape, varied within and among morningglory accessions, and might not be useful traits for segregating morningglory species or accessions within species.

Sources of Materials

[1] Jiffy mix, Jiffy Products of America Inc., Batavia, IL 60510.

[2] Leaf Area Meter, LI-3100, LI-COR Inc., 4421 Superior Street, Lincoln, NE 68501.

[3] Mitutoyo Digital Plastic Caliper available from Forestry Supplier, Inc., 205 West Rankin Street, Jackson, MS 39201.

[4] Statistical Analysis Systems (SAS) software, Version 8.3. SAS Institute Inc., Box 8000, SAS Circle, Cary, NC 27513.

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